

MODERN SOUND-STAGE CONSTRUCTION

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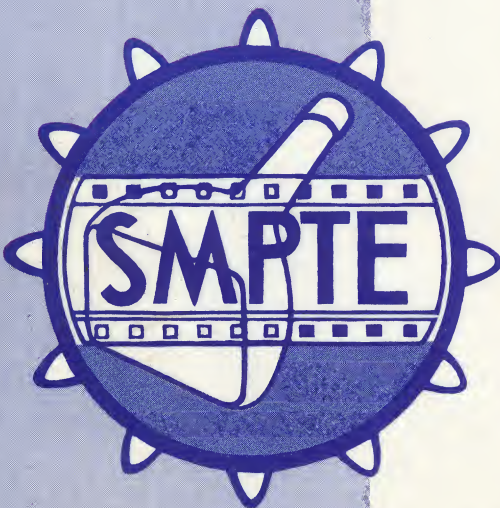
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SUMMARY:

During 1965 a number of major studios (Columbia, Republic, 20th Century-Fox) constructed new sound stages, chiefly for television film production. The stage sizes were in the order of 14,000 sq. ft. of floor area (approximately 100' x 140') with 35' height to the lower chord of trusses and 50' height to highest point on roof. Construction was always 6" thick tilt-up concrete walls, with 20' wide panels, and columns between panels poured after erection to assure sound-proof joints. Some roofs (depending on the location) carried an extra 2" thick layer of poured concrete over the standard fiberboard-plywood construction, while the large stage doors consisted of 6" thick concrete panels with leading and overhead edges in 2" deep sound-absorbently lined pockets to assure efficiently sound-retarding seals.

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A MAXIMUM PERMISSIBLE SOUND-PRESSURE LEVELS IN SOUND STAGE

B AUTOMOBILE TRAFFIC

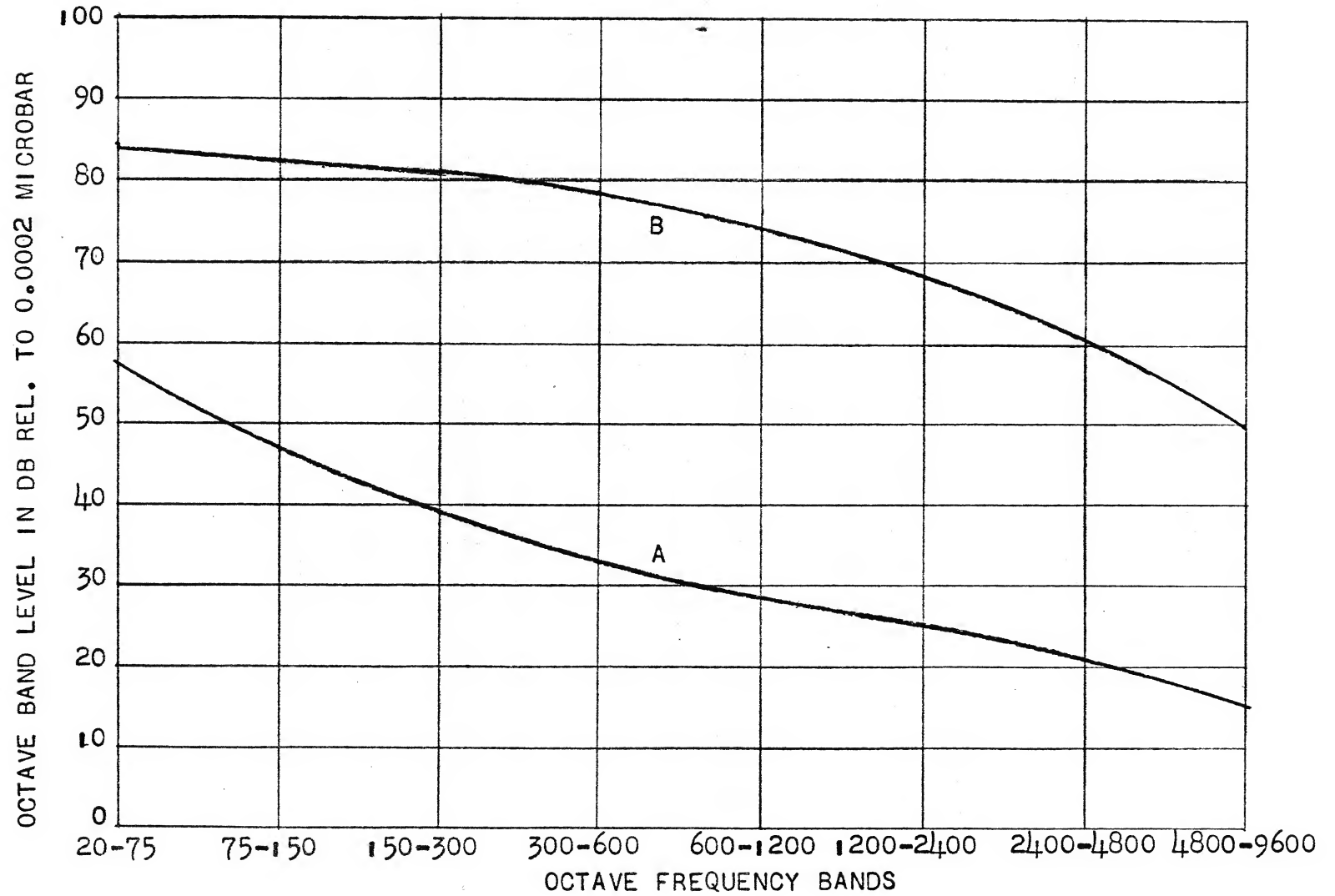


FIG. 1

Planning for good recording conditions in a sound studio is not unlike planning for a quiet hospital or church. It was begun with a noise survey of the proposed site, done with graphic recording equipment to obtain statistical information in respect to time-frequency of peak sound-pressure levels. The survey was implemented with an octave band analysis to learn the predominant frequencies of the noise.

The survey was followed by an investigation of existing airplane traffic about the proposed site, together with an estimate of possible future conditions. Inquiries at airports about Los Angeles, California, regarding the number of take-offs and landings per year brought to light the following interesting figures:

Airport	Number of Take-Offs and Landings (1964)	
	Yearly	Daily (Average)
Santa Monica	289427	792
Lockheed	75000	205
International	365536	1000
Van Nuys	386063	1055
TOTAL	1,116,026	3,052

Note that 3052 take-offs and landings per day averages to more than 2 per minute!

Figure 1 shows the sound-pressure levels for automobile traffic at a particular building site in Hollywood and the maximum permissible sound-pressure levels for a sound recording stage, both curves drawn as a function of frequency. The difference between the curves represents the required noise reduction characteristic of the sound stage. The noise reduction is not necessarily equal to the transmission loss of the stage

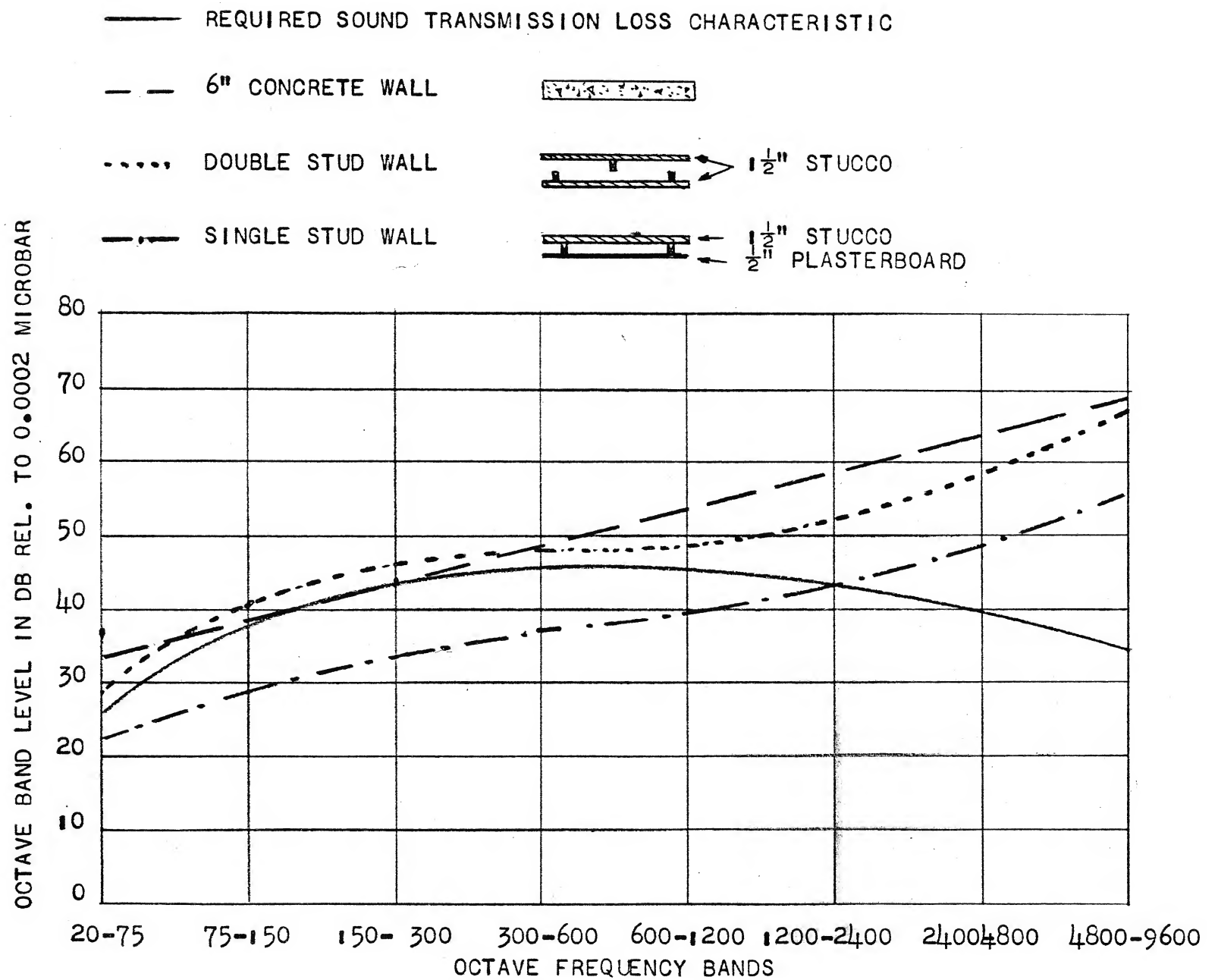


FIG. 2

walls, except at the higher frequencies, when the absorptivity of the interior treatment approaches unity. This may be shown as follows:

$$NR = 10 \log \frac{A}{T} = 10 \log \frac{aS}{tS} = 10 \log \frac{a}{t} = 10 \log a + 10 \log \frac{1}{t} = 10 \log a + TL$$

where A = total absorption in sound stage, sabines

$$= aS$$

a = absorptivity of walls and ceiling (all treated alike)

S = total interior surface, sq. ft.

T = total transmittivity

$$= tS$$

t = sound transmission coefficient of walls and ceiling (assumed alike)

TL = transmission loss

Thus, when $a = 1$, the noise reduction is equal to the transmission loss of the walls. When $a = .25$, as at 100 cps, a -6 db correction factor has to be added to the transmission loss to arrive at the correct noise reduction. The reason for this is that at the low frequencies there occurs a sound pressure build-up in the stage, due to the incomplete absorption. In other words, if say 34 db of noise reduction is required at 125 cycles, the transmission loss of the wall has to be 40 db in order to achieve the required maximum sound-pressure level permissible in the stage.

Figure 2 shows the sound-transmission loss characteristic of three different wall constructions. Such sound attenuation curves should be viewed with a degree of caution, and termed laboratory results, not field reports. Wood and metal stud constructions, together with some masonry work, rarely prove as sound insulative in the field as in the laboratory where workmanship employed for the partition is generally of a much higher order than in

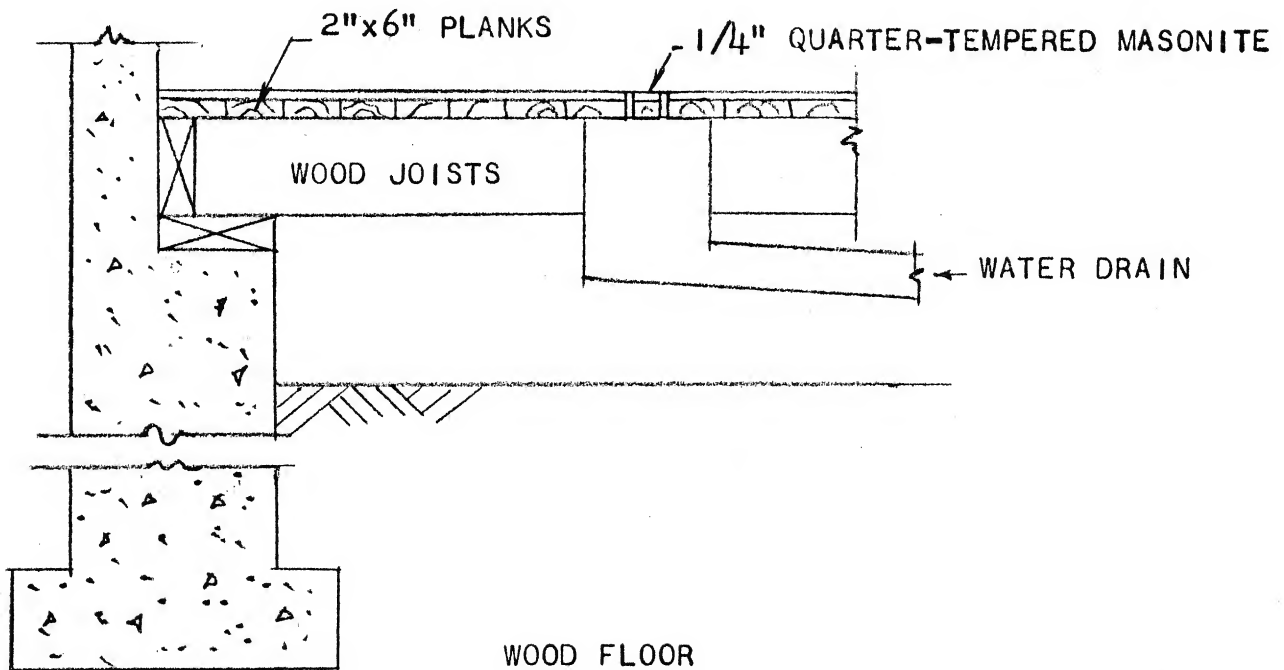
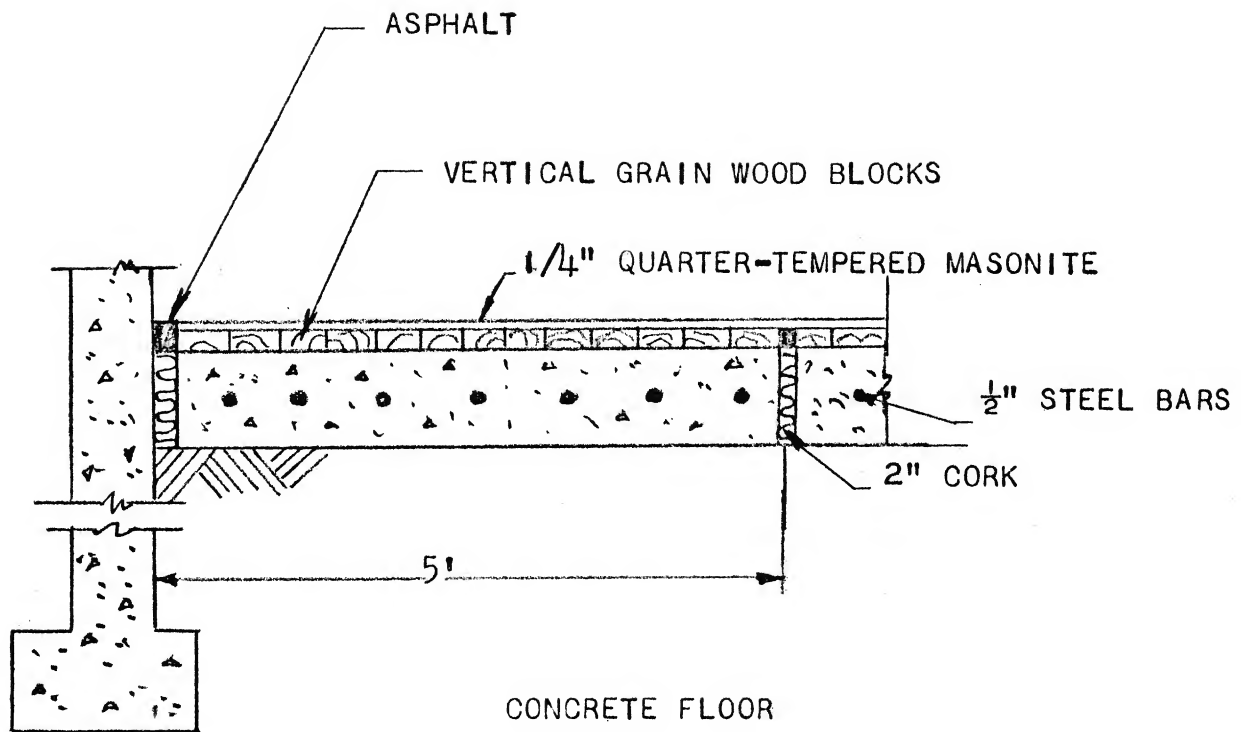


FIG. 3

the field. Also, laboratory tests generally ignore sound "flanking" effects about room corners, vertically as well as horizontally.

We come now to the problem of impact or mechanical-vibration isolation between sound stages, so that set-construction can be carried out in one enclosure while sound recording takes place simultaneously in an adjoining one. The solution lies in structural isolation or discontinuity between such adjacent enclosures - including a generous separation in space between the stages. The recommended minimum separation of adjoining continuous foundation walls should be in the order of 4 ft. When pilings or caissons are used in light soil, the physical separation of the adjoining stage walls may be less than 4 ft., on account of the greater vibration attenuating quality of such ground.

Impact transmissibility between stages is to some extent dependent on the type floor used in the stages. Not all major studios are agreed on a wood floor applied to a concrete slab as the most desirable bearing surface for camera cranes, microphone booms, etc. On account of the often unpredictable locations within a stage of so-called camera pits - sub-surface enclosures 20' x 20' by 10' deep - wood floors on wood joists are sometimes preferred since they can be cut into unlike concrete floors. They also permit simpler drainage facilities for the water required in rain scenes, besides reducing the impact transmissibility between stages. When camera pits are permanently installed in a stage with concrete floors, they can be covered with solid lids light enough to be lifted out of place by studio cranes. In such stages the water from rain scenes is generally pumped out by small auxilliary pumps although a few of the new stages with concrete floors did have drain pipes

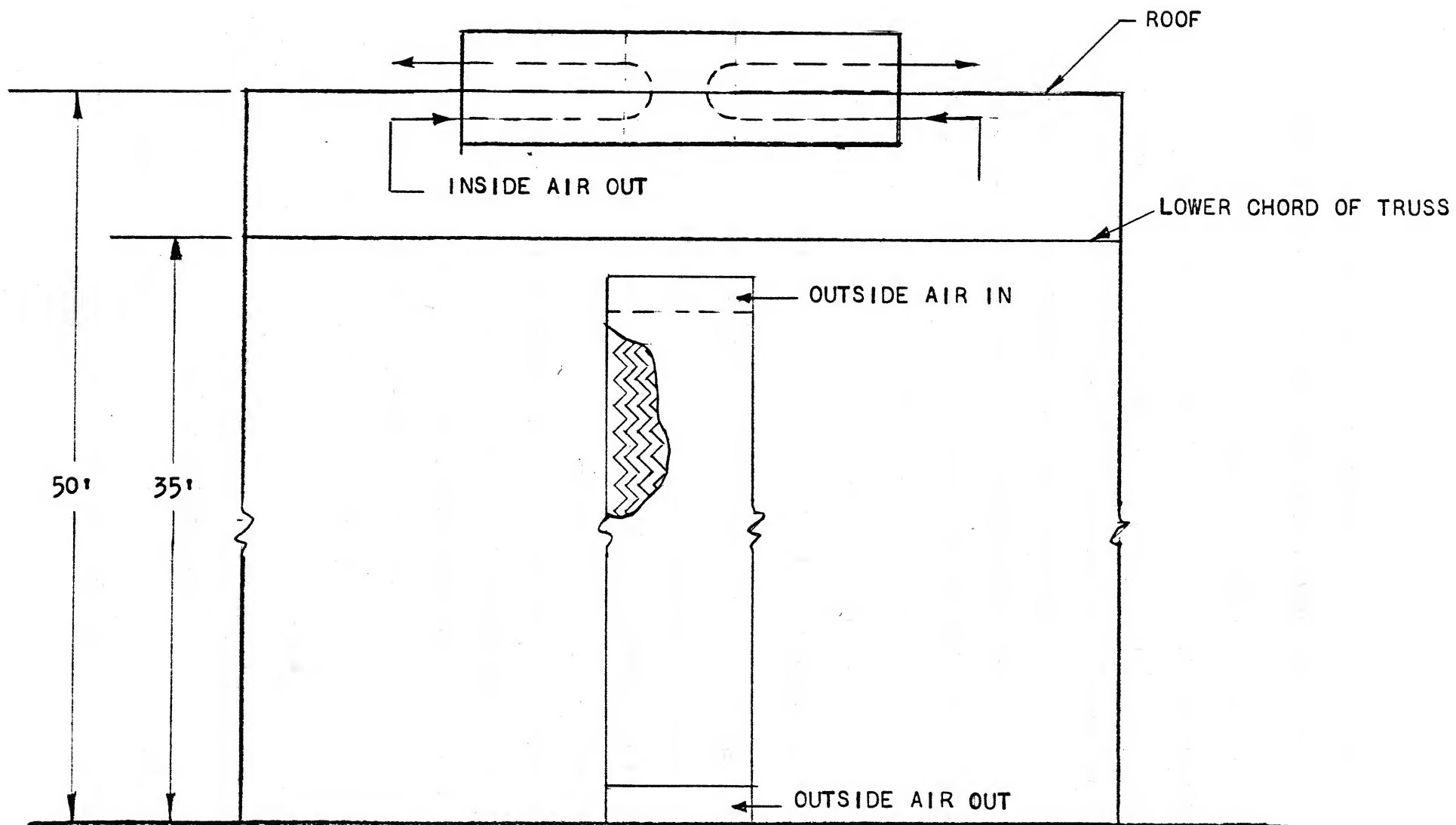


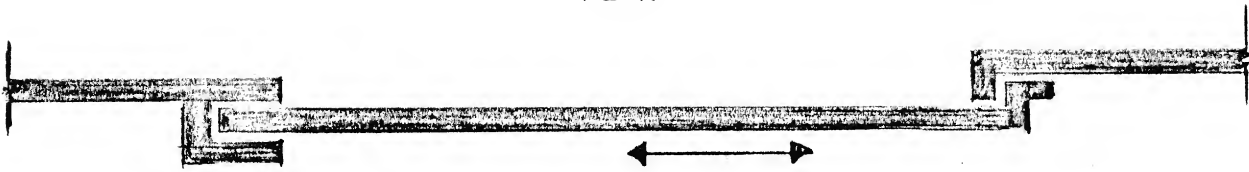
FIG. 4

embedded in the concrete. When the script requires a person to descend into a basement, the set is "built up" (above the stage floor) in such stages which do not have permanent camera pits installed in the floor and where it is not desired, for one reason or another, to cut a hole in the floor resting on wood joists.

When concrete slabs are used for floor foundations, it is important to isolate them from all wall foundations by a 2" thick layer of asphalt at the perimeter, and not to permit mechanical connections such as water pipes, conduits, drains, etc., to "short-circuit" wall and floor foundations. The use of vertical grain wood blocks of the type described in Motion Picture Research Council Bulletin No. 58,456A provides undoubtedly the best floor, both from the point of having very little transmissibility to vibrations and from the point of durability, that is, freedom from squeaks, warpage, moisture resistance, etc. In more economical constructions, 3/4" plywood is "shot" or nailed with hardened nails directly to the concrete sub slab after which 1" x 4" flooring is nailed to the wood base, with studio board laid on the flooring. Figure 3 shows the two types of wood floor discussed above.

Sound stages rarely are air-conditioned, employing only a ventilating system. The air-intake is usually through holes in the walls near the roof line, with the air outlets close to the floor. The air is taken out of the stage near the roof, and all ducts are heavily lined accoustically and/or carry "splitters" or corrugated partitions inside the duct for better noise attenuation. Air change may be effected either in 5 or 10 minutes by a 2 speed motor, the slower speed change being quiet enough so that sound-recording can take place simultaneously. Since a sound

PLAN



ELEVATION

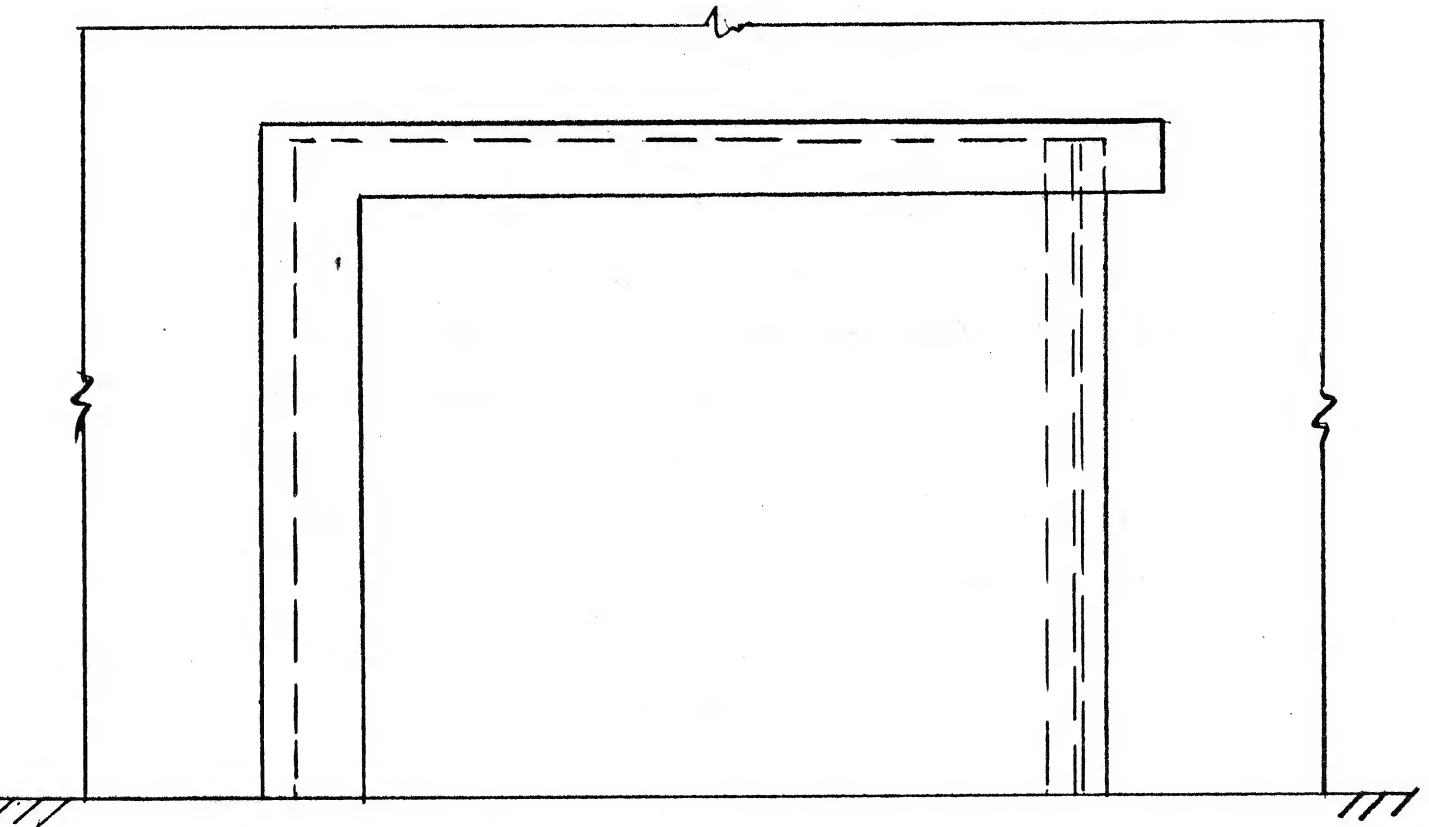


FIG. 5

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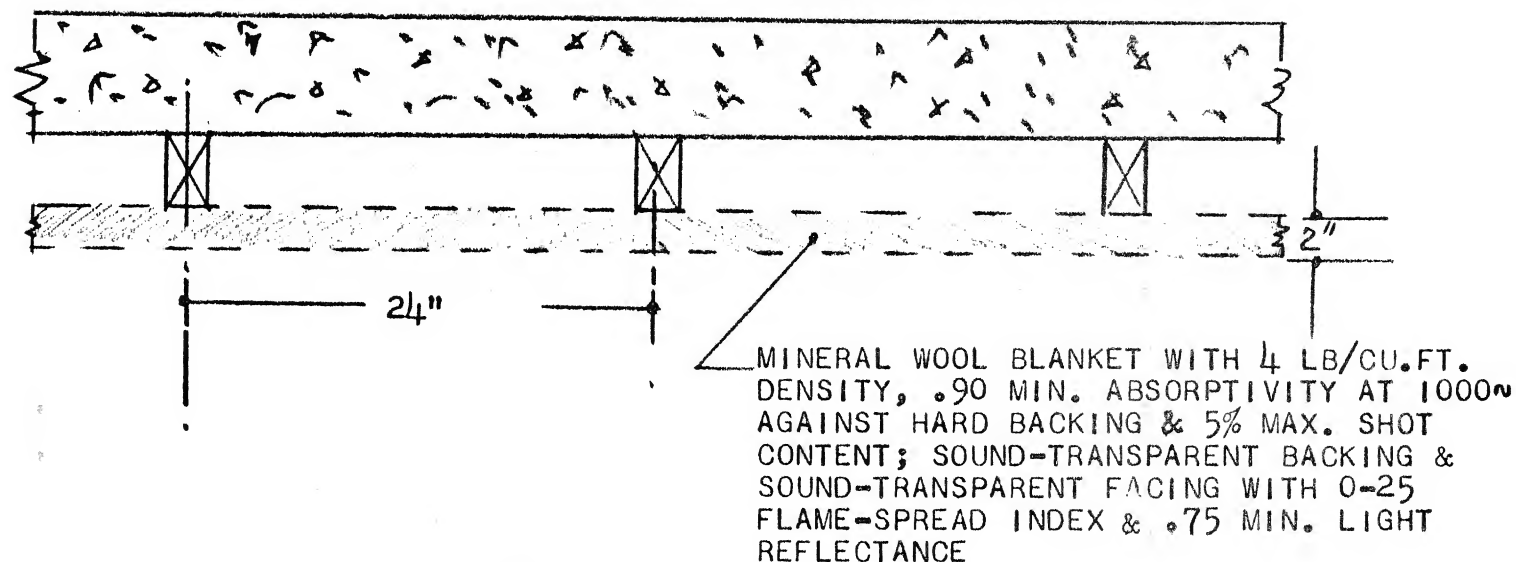
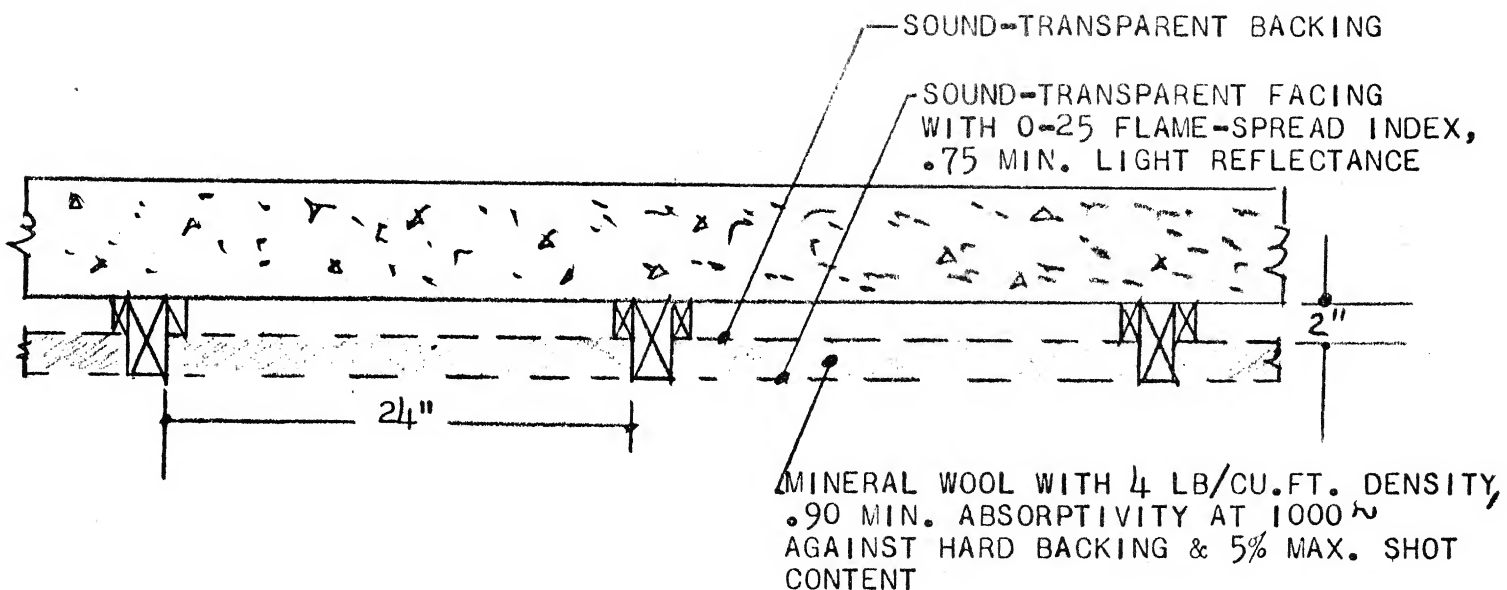
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stage rarely has a volume smaller than 500,000 cubic feet, and the air-change has to occur in 5 minutes, 100,000 cubic feet of air have to be moved per minute. With air speed of 1000 ft/min, the total duct area comes to 100 square feet. Figure 4 shows a generalized lay-out for such a ventilating system.

The doors to a sound stage should be comparable to its walls in sound insulation. Because pound for pound, concrete is the cheapest building material, such doors are most economically built with this material. To assure a good durable seal, the leading edge of the door fits into a 2 ft. deep sound-absorbently lined concrete pocket, with the overhead edge moving in a similar recess. Figure 5 shows a schematic of such a door. Operation of such a door is accomplished by an electric motor, with proper safety features applied to the leading edge to insure instant stopping of the door should a person be walking through the opening while the door is being closed. Carriage of the door which often weighs 20 tons or more is usually accomplished by ground wheels rather than overhead rollers, to economize on the support structure.

The acoustic treatment, see Fig. 6, on the interior surfaces of the stages consists invariably of some sort of rockwool or fiberglass 2" thick weighing not less than 4 lbs. per cubic foot, with the "shot" or solid particle content less than 5% by weight, and backed by a 2" deep air-space. Coverage of the acoustic treatment is generally by glass cloth, to obtain both a high light reflection coefficient and a low flame-spread index. The lower 14 ft of the wall treatment are protected by galvanized hardware cloth or other wire mesh. A wooden 3# x 10" nailer is applied to the walls some 14 ft above the floor to provide anchorage for set braces.



TWO TYPES OF ACOUSTIC TREATMENT FOR SOUND STAGE

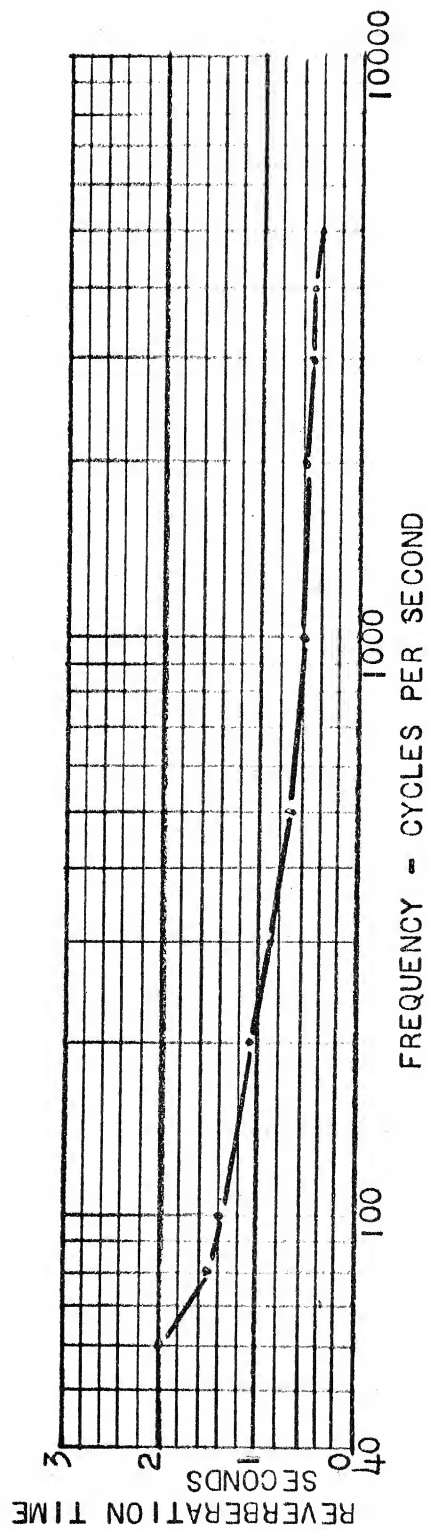
FIG. 6

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The 2" (minimum) air-space behind the mineral wool is required to increase the low-frequency absorption coefficient. In this respect, the combination wood and air-space is practically equivalent to a wool of the same thickness, and hence is a very economical substitute. In the olden days when sound stages were constructed of wood studs and stucco, and the mineral wool blanket was applied over a fiberboard nailed to the interior faces of the studs, the panel action of the fiberboard was very instrumental in increasing the low-frequency absorption coefficient. With concrete stage walls, however, no such accessory sidewall absorption action takes place.

The underside of the roof rafters do carry a sheet of fiberboard, however, to which the mineral wool is applied. Thus, there is some low-frequency panel-action at the underside of the roof, with the result that the low-frequency reverberation becomes comparable to that obtained in framed sound stages.

The two most important acoustic tests for a sound stage are the measurement of the reverberation time characteristic, that is, the variation of reverberation time with frequency, and the noise-level of the unoccupied stage. In respect to reverberation time calculations from known absorptivity values of the wall material and in respect to the measurement of the time itself it is interesting to note that there are at present at least a half-dozen equations and that many methods of measurement. The formula most suitable for this purpose may be termed the Fitzroy equation, after Dariel Fitzroy, who described it in the July, 1959, J1. of the Acoustical Society of America under the rather modest title "Reverberation Formula Which Seems To Be More Accurate with Non-uniform Distribution of



REVERBERATION CHARACTERISTIC OF REPUBLIC PRODUCTIONS
SOUND STAGE NO.

FIG. 7

Absorption". It is written as follows:

$$T = \frac{.1V}{S^2} \left[\frac{xy}{\lg(1-a_{xy})} + \frac{xz}{\lg(1-a_{xz})} + \frac{yz}{\lg(1-a_{yz})} \right]$$

where x = width of room

= 100 ft. in the case of the newly build Republic Productions Stage No. 19

y = length of room

= 130 ft.

z = height of room

= 46 ft.

a_{xy}, a_{yx}, a_{yz} = average absorptivities of a pair of opposite surfaces in the room

S = total interior surface of room sq. ft.

= 47,000 sq. ft.

V = volume of room

= 600,000 cubic feet

At 500 cps, the average absorptivity of the sidewalls is .97; but of the floor-ceiling combination it is only half as large, .485, because the quarter-tempered Masonite floor contributes only negligibly towards the total absorption of this pair of opposite surfaces. Note that the denominator terms in the bracket are not the absorptivities (which they could be in "live" rooms) but the natural logarithms of the reflectivities $(1 - a)$. Thus for each of the pair of opposite sidewalls the denominator is 3.5 while for the floor-ceiling combination it is only .66. Thus

$$T = \frac{.1 \times 600000}{47000^2} \left[\frac{4600}{3.5} + \frac{5980}{3.5} + \frac{13000}{.66} \right]$$

$$= .0000271 (1315 + 1710 + 19700)$$

$$= .615 \text{ seconds}$$

Note in the next to the last equation above how little the first two terms in the bracket contribute towards the total reverberation time in the room. By far the most determinative term is the floor (or ceiling) area divided by the logarithm of the reflectivity of the floor-ceiling combination. This is only "natural", because the reverberations in the horizontal directions can die away very rapidly, since all sidewalls are highly absorptive. However, sound in the vertical direction can decay only slowly, because the floor is very hard acoustically. Indeed, one could make the sidewalls considerably less absorptive without changing the reverberation time in the sound stage very little at 500 cps.

This is not permissible, however, for the reason that motion picture sets are frequently built near walls, with the actors facing them. Since the "liveness" of a scene is determined chiefly by the set materials, and delayed reflections from the sidewalls are unacceptable, the sidewalls must remain highly absorptive.

At the low frequencies the sidewalls have a greater effect on the total reverberation in the room, because the logarithmic values of the reflectivities are not so widely different.

The roof consisted of wood trusses and rafters to the underside of which a layer of fiberboard was applied for the backing of the 2" thick mineral wood. This surface, thus, was able to act as a sound-absorbing diaphragm at the low frequencies. Previously made sound-absorptive tests at 100 cps provided an absorption coefficient of .60 for the roof, compared to an absorption coefficient of only .30 for the sidewalls, where the 2" thick mineral wood was backed only by a 2" thick air-space (in front of the concrete panels). According to the Fitzroy equation, the reverberation time calculated to be 1.2 seconds.

As noted before, there are now a number of reverberation time measurement methods, the most recently described consisting in recording a pistol shot on magnetic tape, reproducing this recording backwards and through an appropriate band-pass filter, and then integrating the output through a special network.* In the case of Republic Productions Stage No. 19, the reverberation time measurements were made with a high-speed level recorder and both filtered gun-shots and sinusoidal signals generated by a large loudspeaker system. The results of the measurements are shown on Figure 7. The differences in reverberation times measured with the two signals, and for that matter, between the measured and calculated times, were in the order of $\pm 10\%$, not a large difference for this type of acoustic measurements.

In conclusion it should be noted that in many fields of human endeavor progress is often based on previous and diverse improvements lumped into a new mass and heavily leavened with innovations. This is the case here. Concrete walls for sound stages were used in the early days of sound-film recording, because it was felt then already that the heavy masses were superior in sound-insulating quality. However, the stages were not of the tilt-up type, and proved rather expensive. With the extensive use (particularly in California) of horizontally cast and heavily reinforced concrete slabs for all types of highly weather-resistant, fire-proof, and quiet buildings, it was only natural to consider this method of construction also for sound stages.

The authors wish to give credit to the firm of King, Benioff, and Associates, structural engineers, for working out many of the structural problems connected with the design and building of the subject sound stages, and the Ferguson Door Co. for working out the details of the doors.

* "A New Method of Measuring Reverberation Time" M. R. Schroeder Jr. Acoust. Soc. March 1965 P. 409